7. MARINE-NONMARINE RELATIONSHIPS IN THE CENOZOIC SECTION OF CALIFORNIA*

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INTRODUCTION

Highly fossiliferous marine sediments of Cenozoic age are widely distributed in the coastal parts of central and southern California, as well as in the Sacramento-San Joaquin Valley region farther inland. Even more widespread are nonmarine, chiefly terrestrial, sequences of Cenozoic strata, many of which contain vertebrate faunas characterized by a dominance of mammalian forms. These strata are most abundant in the Mojave Desert region and in the interior parts of areas that lie nearer the coast.

Marine and nonmarine strata are in juxtaposition or interfinger with one another at many places, especially in the southern Coast Ranges and the San Joaquin basin to the east, in the Transverse Ranges and adjacent basins, and in several parts of the Peninsular Range region and the Coachella-Imperial Valley to the east. These occurrences of closely related marine and nonmarine deposits permit critical comparisons between the Pacific Coast mammalian (terrestrial) and invertebrate (marine) chronologies, and it is with these comparisons—examined in the light of known stratigraphic relations—that this paper is primarily concerned.

The writers have drawn freely upon the published record for geologic and paleontologic data. In addition, Durham has reviewed many of the invertebrate faunas and has checked the field relations of marine strata in parts of the Ventura and Soledad basins, the Tejon Hills, and the Cammatta Ranch; Jahns has studied new vertebrate material from the Soledad basin and has mapped this area and critical areas in the vicinity of San Diego, in the Ventura basin, and in the Caliente Range; and Savage has made a detailed appraisal of the vertebrate assemblages, and has mapped critical areas in the Tejon Hills. The areas and localities that have been most carefully scrutinized are shown in figure 1.

The manuscript was reviewed in detail by G. Edward Lewis of the U. S. Geological Survey, who made numerous comments and suggestions that resulted in considerable improvement. It should be noted that his views are not wholly compatible with some of those expressed in this paper, and that his critical appraisal thus was particularly helpful.

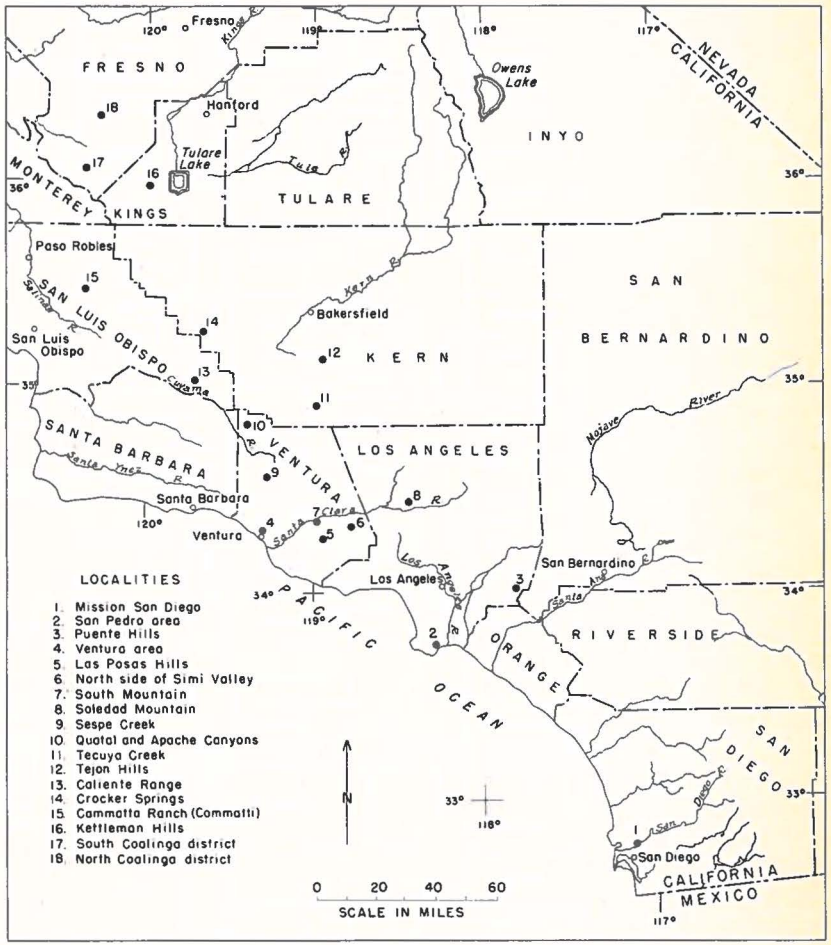

FIGURE 1. Index map of a part of southern California, showing locations of marine-nonmarine tie-ins discussed in the text.

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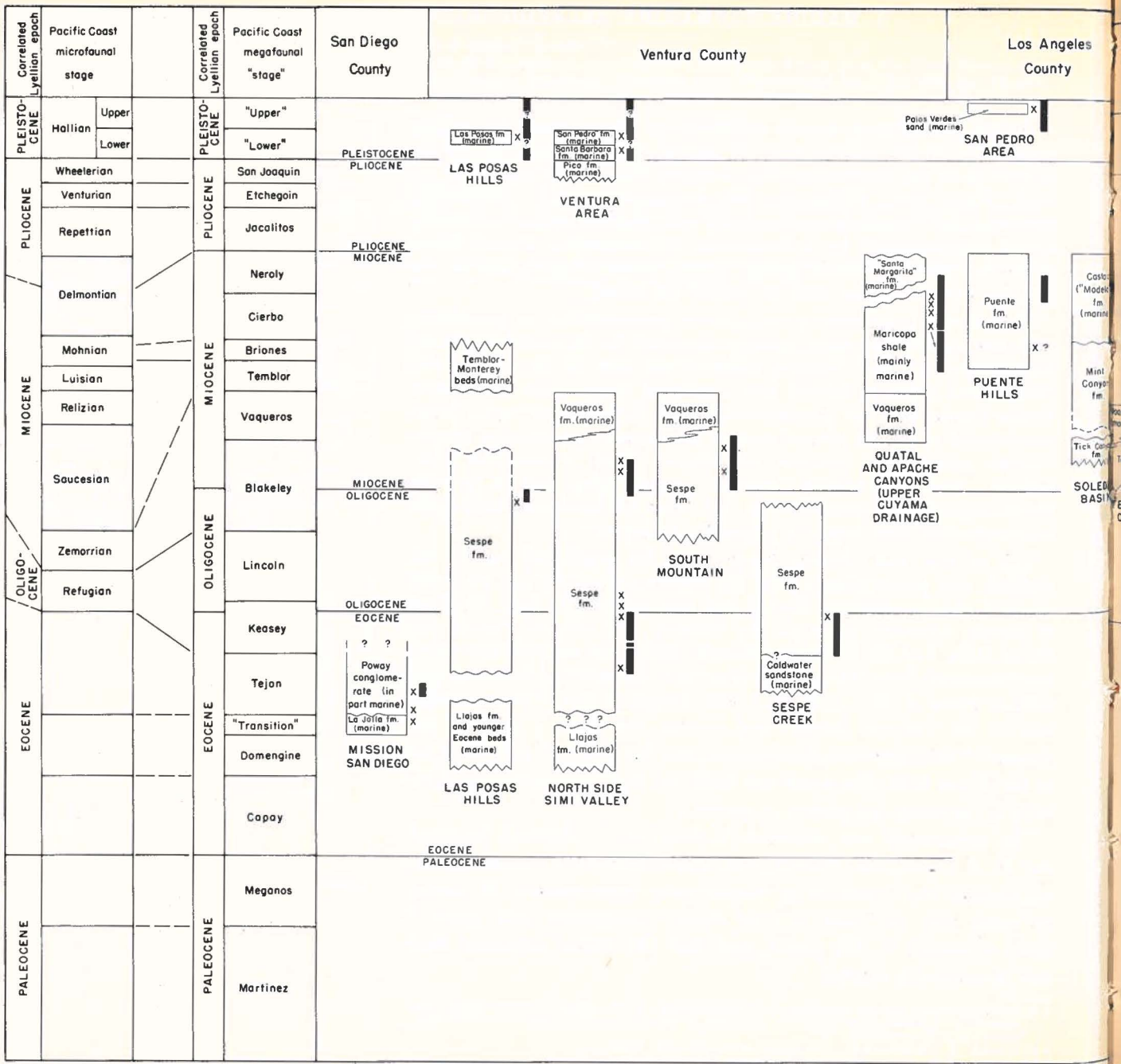
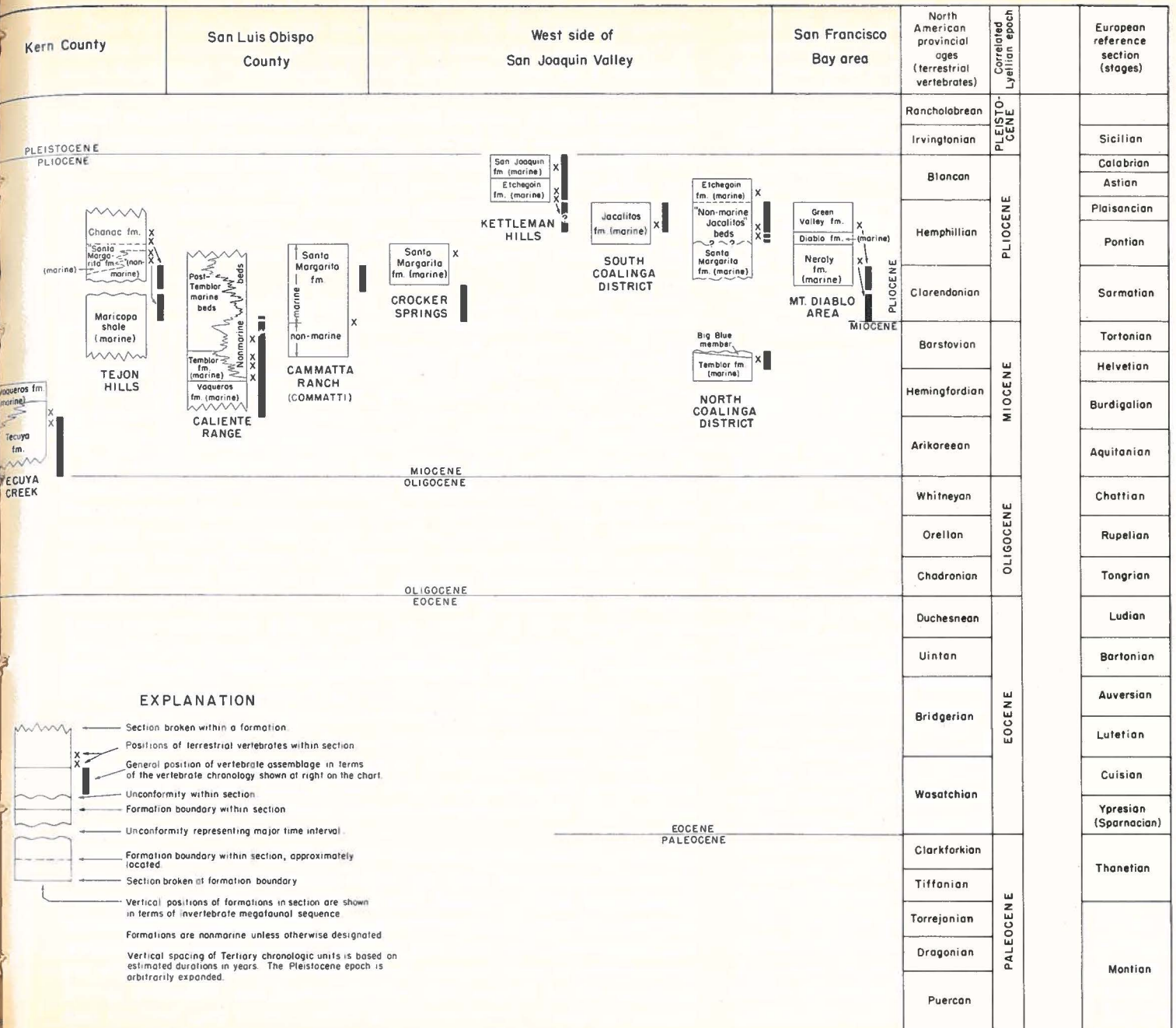


FIGURE 2. Summary of Cenozoic marine-nonmarine relationships in California, showing various correlations of microfaunal, megafaunal Stirton (1951),



nd terrestrial vertebrate occurrences with the European reference section. Based in part upon data from Weaver, et al. (1944), Simpson (1947), thers noted in text.

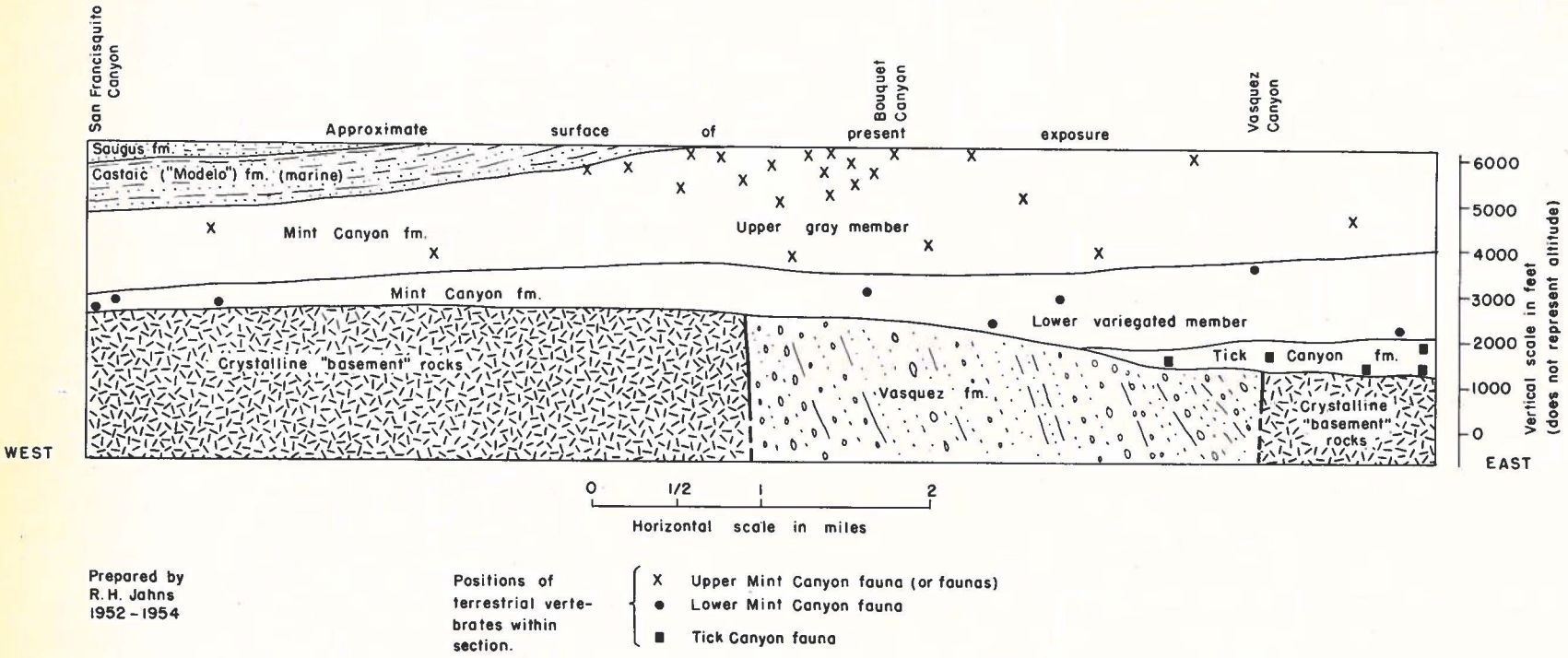


FIGURE 3. Diagrammatic section showing relations of stratigraphic units, vertebrate faunas, and occurrences of specifically identifiable fossils in the Tick Canyon, Mint Canyon, and associated formations of the Soledad basin.

GENERAL FEATURES OF CORRELATION

Two chronologies are now in common use in the Cenozoic marine sections of California. One chronology is based on "metazoans," or more familiarly "megafossils," and has been used as a standard in the correlation chart of Weaver, et al. (1944). This chronology is based on the distribution of megafossil faunas within formations and sequences of formations, and has evolved in a rather haphazard and undisciplined manner. The units within the chronology have been called stages and are based on the faunas of well known and presumably characteristic formations. Each stage is named after the presumed typical formation; thus, for example, the "Vaqueros stage" has been conceived from the "Vaqueros fauna" of the Vaqueros formation.

The other marine chronology is based on distribution of Foraminifera in continuous sections (see, for example, Kleinpell, 1938). The units of this microfaunal chronology also are termed stages, but their names are not based on formational units. The studies leading to the proposal of the various microfaunal stages have all been made within the last 25 years, and have resulted in a carefully disciplined chronology applicable to beds that contain Foraminifera.

The widely used mammalian chronology that has been applied to terrestrial strata in North America comprises basic units that have been termed "provincial ages." These provincial ages have been assigned epochal positions in the Lyellian chronology (i.e., reference to epochs such as Eocene or Oligocene); these positions do not agree in all instances with the epochal positions assigned to correlative intervals on the basis of invertebrate fossil assemblages, and vertebrate paleontologists differ as to the extent of the disagreement. Some lack of correspondence certainly exists, however, and for this reason discrepant age assignments commonly are given to the same formations by the invertebrate and the vertebrate paleontologists, as noted for several California occurrences in the following sections of this paper. When these discrepant epochal assignments are analyzed, however, they may be found to refer to the same "absolute" age. It is to be hoped that, in the future, vertebrate and invertebrate paleontologists can agree on identical boundaries for the Lyellian epochs.

Lyellian dating of Pacific Coast Cenozoic strata involves repeated reference to, and comparison with, the type European sections of the Tertiary as defined by Lyell and Deshayes. This immediately raises certain complications, in part because the types of the various series do not occur in superposition and thus their boundaries are not adequately controlled, and in part because there is disagreement among geologists and paleontologists with respect to the positions and relative ages of vertebrate and invertebrate fossils in certain parts of the European section.

Many investigators believe that the mammalian geochronology, based on the common occurrence of mammalian genera in different continental areas, offers the greatest possibilities for refinement in Cenozoic intercontinental correlations. This view is founded mainly upon the following premises:

1. Mammalian genera that at present are considered significant to intercontinental correlation are characterized by limited chronologic ranges in comparison to similarly widespread genera of other groups of animals in the Cenozoic.
2. Genera of restricted chronologic range are found in both Europe and California.
3. These genera were able to disperse and migrate in a manner relatively independent of environmental control as compared to most other organisms.
4. The critical mammalian genera moved rapidly enough so that the lag of time in their dispersal and the time differential of their appearance on different continents *(homotaxis)* are insignificant in time-stratigraphic terms of stage-age magnitude.

Others argue that inter-continental migrations of mammalian genera can be effectively blocked by narrow marine barriers for epochs of geologic time, and hence that a complete and accurate record of land connections might be critical in evaluating certain differences in mammalian forms on different continents. Knowledge of the geography and chronology of such connections is still far from complete, but points 1 and 2 above would suggest that this difficulty need not be a serious one. It also is argued that the epochal boundaries in the marine section commonly correspond to major episodes of tectonic activity, and hence constitute logical breaks in the sequence, but the available data suggest that this concept is considerably over-simplified.

It cannot be denied that marine invertebrate fossils ordinarily are much more abundant and widespread than terrestrial vertebrate fossils, but this oft-repeated point has little real bearing on the basic problem in a region where fossiliferous marine and nonmarine strata appear in various parts of the same section. In California, for example, there is no lack of marine-nonmarine tie-ins within the upper Miocene-lower Pliocene part of the section, where the most vexing discrepancies between vertebrate and invertebrate dating occur. Thus it should be quite feasible to bring the Lyellian epochs of the marine invertebrate chronology into adjustment with those of the mammalian chronology, especially if paleontologists can reach agreement as to the positions of the epochal boundaries in the type areas of Europe.

It is not the purpose of this paper to recommend specific adjustments between the vertebrate and invertebrate chronologies, but it does seem desirable to indicate the position and magnitude of some of the discrepancies that are known to exist. These are summarized graphically in figure 2, which indicates the stratigraphic and paleontologic relationships in 20 areas of Cenozoic rocks in California.

The vertical positions of the rock units in each area are plotted in accordance with the invertebrate megafaunal sequence, which is shown on the left-hand side of the chart. The occurrences of terrestrial vertebrate fossils within each section are shown as accurately as possible, and the adjacent vertical bars indicate the positions of these assemblages in terms of a vertebrate chronology that is employed by many, though not all, vertebrate paleontologists. This chronology is shown on the right-hand side of the chart. Thus any discrepancy between the invertebrate and vertebrate scales is reflected by a difference between the vertical position of that part of the rock unit in which the vertebrates are found and the position of the bar corresponding to the vertebrate assemblage in question.

Boundaries between Lyellian epochs are indicated by horizontal lines across the chart except in the instance of the Miocene-Pliocene boundary, which is at different levels in the vertebrate and invertebrate sequences that are shown. This conflicting boundary assignment arises because the vertebrate-bearing rocks assigned to the Pontian and Sarmatian of Europe, which commonly are regarded as equivalents of the Hemphillian, Clarendonian, Neroly, Cierbo, and Delmontian (fig. 2), do not occur in the type areas of the Miocene and Pliocene section in Europe and were not included in the type description. Assignment of the Pontian and Sarmatian (or their subdivisions or correlatives) to an epochal position has varied chiefly according to the paleontologic discipline involved. In the mammalian chronology, Pontian and Sarmatian correlatives often have been placed in the Pliocene, whereas in the marine chronologies they generally have been placed in the Miocene by molluscan paleontologists (e.g., Clark, et al., in Weaver, et al., 1944 chart), or have been termed "Mio-Pliocene" or "Miocene-Pliocene" (e.g., Beck, et al., in Weaver, et al., 1944 chart; Kleinpell, 1938) by some micropaleontologists. They also have been regarded as Miocene in continental correlations by some mammalian paleontologists. This purely terminological discrepancy has led to the peculiar situation, noted long ago by Reed and Hollister (1936, pp. 1586-1588), in which "the Lower Pliocene of most vertebrate paleontologists is at least in part the equivalent of the Upper Miocene of the invertebrate paleontologists."

CORRELATIONS IN CALIFORNIA

Poway Conglomerate. The earliest record of land mammals presently known in California is found in the Poway conglomerate and at the top of the underlying Rose Canyon shale of the La Jolla formation (Stock, 1937, 1938a, 1939; Wilson, 1940b), near San Diego (fig. 1). The Poway fauna includes an insectivore, an anaptomorph primate, at least six species of early sciuromorph rodents, a brontothere ("titanothere"), and an amynodont rhinoceros. The total aspect of the assemblage indicates that it is in about the same stage of evolution as the Wagonhound fauna of the Rocky Mountain region, Uintan provincial age (late Eocene), although there are no species in common (except possibly one) between the two areas. Four genera of carnivores are common to Europe and North America in late Eocene time, but none of these has yet been found in the Poway beds; hence, no direct comparison with Europe is possible. The Poway fauna must be compared with the early faunas of the Sespe formation or with the Uinta faunas, which in turn are suggested to be contemporaneous with the European mammals reported to represent the Bartonian or Ludian stages. The position of the Poway mammals with respect to the invertebrates recorded from the formation by Hanna (1927b), Dusenbury (1932), and Cushman and Dusenbury (1934) is not clear, but examination of Hanna's map (1927a) would suggest that the brontothere was obtained from about the same stratigraphic position as Dusenbury's faunule. On the basis of the meager data now available, the relative stratigraphic positions of the other mammal occurrences are uncertain.

According to the chart in Weaver, et al. (1944), as well as the investigators listed above, the marine fossiliferous part of the Poway conglomerate is to be correlated with the Tejon stage. This is about early upper Eocene in local terminology, and is considered equivalent to the Bartonian stage of Europe as shown in the Weaver chart. Cushman and Dusenbury (1934) also correlate their foraminiferal faunule with the upper Claiborne faunas of the Gulf Coast. According to the correlation chart of the Gulf Coast region (Cooke, et al., 1943), the upper Claiborne is about equivalent to the Auversian stage (next older stage than Bartonian) of Europe. On the other hand, the middle Claiborne has yielded a titanothere of late Uintan to Duchesnean type (Gazin and Sullivan, 1942), which raises some complications (fig. 2). It would appear that there is general but not precise agreement that the age of at least a part of the Poway conglomerate is about early upper Eocene.

Sespe Formation. The Sespe formation, which is widely distributed in parts of the Transverse Range and Peninsular Range provinces of southern California, has yielded vertebrate faunas of several different ages. The Tapo Ranch faunas of Stock (1934a, b, c) and Wilson (1940a, c; 1949a, c) are contained in the lower half of the 7,400 feet of sediments referred to the Sespe in the Simi Valley area (fig. 2), and mammals of this fauna occur between 1,830 feet and 3,270 feet above the base of the formation (Stock, 1932a). Here the nonmarine Sespe section is reported to be separated from the underlying marine Llajas formation by an erosion interval (Stock,

1932a), but in places the two formations appear to be conformable (Stipp, 1943). According to Laiming (1941), the youngest marine beds of the Llajas are to be referred to his B-1A zone, which is either late Domengine or "Transition" age in the megafaunal sequence.

The Tapo Ranch fossil vertebrates constitute the earliest mammalian assemblage known from the Sespe formation, and are considered to be of about the same age or a little younger than the Poway fauna. Two faunal stages are recognized (Stock, 1934a, p. 150; 1934b, p. 349) from the fossiliferous part of the Tapo Ranch section. A part of the assemblage is Uintan (late Eocene), and is thought to be contemporaneous with the Myton fauna (Uinta C) of Utah. Species of *Viverravus* and *Miacis*(?), two carnivores, offer a means of comparison with species of these genera reported from deposits of the Ludian stage, from the type area of the Eocene in France, although the Ludian may be younger than Uintan. A distinctly younger part of the assemblage seems to correspond to the fauna from deposits that overlie the Upper Uinta (Uinta C) strata of the Uinta Basin (Stock, 1932a, p. 523; 1934e, p. 625), and hence is probably Duchesnean (latest Eocene).

Although the position of this uppermost Eocene fauna is compatible with that of the invertebrate fauna of the underlying marine strata, complications with respect to the Duchesnean are recognized in other regions. As pointed out by G. E. Lewis (personal communication), *Notiotitanops*, a titanothere found *in situ* in the Lisbon formation of the middle Claiborne group in Mississippi, is closer to *Teleodus* of the Chadron and Duchesne River assemblages than to any other genus, although there are resemblances to *Diplacodon, Protitanotherium,* and *Eotitanotherium* of the Uinta (Gazin and Sullivan, 1942). The marine Lisbon formation, however, is generally regarded as a correlative of the Lutetian stage, or distinctly older in terms of the European reference section (fig. 2).

The upper part of the Sespe section on the north side of Simi Valley has yielded a sparse vertebrate fauna that includes *Archaeolagus*(?) and a leptauchenid (Wilson, 1949b). These forms, which are regarded as Arikareean (early Miocene) in age, occur stratigraphically below an interfingering contact between the Sespe strata and overlying marine Vaqueros strata (fig. 2), and hence are in reasonably good agreement with the mega-invertebrate chronology.

Stock (1938b) described *Teleodus,* a brontothere, from the type Sespe formation of Sespe Creek, north of Ventura (fig. 1). This specimen is dated as Duchesnean (latest Eocene), and it was found 400 feet to 700 feet above the Coldwater sandstone (fig. 2). The paleontological collections of the University of California contain specimens of *Turritella uvasana sargeanti* from the Coldwater strata on Santa Paula Creek, indicating a Tejon age, but Clements (1943) and others have stated that the Sespe formation rests unconformably on the Coldwater sandstone. Thus evaluation of the age relationships is somewhat uncertain, except that the Sespe of the type area is younger than the Coldwater sandstone.

In the South Mountain area, about 20 miles southeast of the type Sespe area, a few mammals have been found in the Sespe formation between 400 and 2,000 feet beneath its contact with the conformably overlying marine Vaqueros formation. These mammals include oreodonts and rodents (Stock, 1934d), and are considered to be of probable Arikareean age (early Miocene). The overlying Vaqueros formation in this area is considered to represent the "lower" Vaqueros by Loel and Corey (1932, correlation table).

Fossil vertebrates also have been obtained from the upper part of the Sespe formation in the Las Posas Hills, approximately 6 miles south-southeast of the South Mountain area (fig. 1). An erosional break separates the terrestrial beds from overlying marine strata of Miocene age (fig. 2). The fauna, which is large and includes much relatively complete material, is wholly different from the other Sespe faunas (Stock, 1933a, b, 1935c; Wilson, 1949b). The rhinoceroses, horses, camels, carnivores, rodents, and other forms are represented, but oreodonts are absent. Although the fauna can be correlated in a general way with that from the lowest fossiliferous beds of the Sespe formation at South Mountain (Stock, 1934d, p. 523), it appears to be Whitneyan (late Oligocene), rather than Arikareean (early Miocene), in age (Stock, 1933a, pp. 26-27; 1933b, p. 31; Wilson, 1949b, p. 63).

Tecuya Formation. At Tecuya Creek, about 40 miles north of the South Mountain area (fig. 1), a fauna of Arikareean age occurs in red beds of the Tecuya formation on the north side of the Tehachapi Mountains (Stock, 1920, 1932c). The fauna includes squirrel, rhinoceros, oreodont, dog, and a small deer-like animal. According to the available evidence, the Tecuya beds both underlie and interfinger with strata of the Vaqueros formation (fig. 2). Loel and Corey (1932, correlation table) regard the Vaqueros formation of this area as considerably younger than the basal Vaqueros at South Mountain, and consider it to represent their "upper" Vaqueros.

Thus in two places, South Mountain and Tecuya Creek, terrestrial beds that lie beneath the Vaqueros formation are dated as lower Miocene in the vertebrate chronology, although it is well to note that the Aquitanian stage of Europe, with which the lower Arikareean is correlated (Simpson, 1947), is not contained in Lyell's type Miocene, and that it has been considered as part of the upper Oligocene by some investigators. If the vertebrate evidence is significant, it would appear that the Vaqueros "stage" must be at least in part a

correlative of the upper Aquitanian or perhaps even the lower Burdigalian of Europe. This contrasts with the correlation indicated for the "micro" classification in the chart of Weaver, et al. (1944), where the Vaqueros is indicated as being at least in part as old as the Rupelian stage of Europe.

Nonmarine Beds of the Caliente Range. From the Caliente Range, near the southeast corner of San Luis Obispo County (fig. 1), Dougherty (1940) has described land mammals that occur in a thick section of nonmarine beds. After detailed study of the intergrading relationships between marine and nonmarine sediments in this area, he concluded that the fossiliferous beds are at the same or at a slightly lower stratigraphic level than rocks corresponding to the upper part of the Relizian stage, and that they are to be correlated with the uppermost type Temblor formation and with a part of the overlying Gould shale (fig. 2). Much of the mammalian assemblage described by Dougherty is characteristic of Hemingfordian (mid-Miocene) faunas, but other parts of the assemblage may be Barstovian (late Miocene) or younger. Indeed, the antilocaprid found highest in the section at Padrones Spring (Calif. Inst. Tech. Loc. 170 and Univ. California Mus. Paleo. Loc. V2704) is a type that might be dated as not older than Clarendonian (early Pliocene). The nonmarine sediments of the Caliente Mountains area appear to represent a large span of later Cenozoic time (fig. 2), and the vertebrate assemblages may represent two or more distinct faunas, each of which can be correlated with a different part of the marine section (Eaton, Grant, and Allen, 1941, p. 230). It is clear that this area of marine and terrestrial sediments offers interesting stratigraphic problems for future study.

Mint Canyon and Tick Canyon Formations. The Mint Canyon formation of the Soledad basin, in northwestern Los Angeles County (fig. 1), has been the major focal point in southern California about which controversy over the Miocene-Pliocene boundary has swirled. The difficulties have stemmed in part from a discrepancy between the invertebrate and some of the vertebrate chronologies, as noted in a foregoing section of this paper, and in part from interpretations based upon vertebrate faunas whose stratigraphic positions were imperfectly known. A detailed study of some of the nonmarine strata in the Soledad basin (Jahns, 1940) demonstrated that a well-defined fauna, comprising forms distinctly older than all the others known from the section, represents the lowermost beds of the Mint Canyon formation as originally defined by Kew (1924, pp. 52-54). This fauna comprises rodent, horse, camel, and oreodont remains of Arikareean and possibly earliest Hemingfordian age (fig. 2), and the beds in which it occurs are now included in the Tick Canyon formation, which is separated by a slight erosional break from the overlying Mint Canyon formation as redefined (Jahns, 1940, pp. 163-166).

Further study has shown that at least two distinct vertebrate faunas are present in the Mint Canyon formation as now restricted. The older of these is in large part undescribed, so far as the published record is concerned. It occurs in the lower one-fourth to one-half of the formation, which is characterized by relatively fine-grained and variegated strata (fig. 3). Fossil material from the Bouquet Canyon and San Francisquito Canyon areas includes representatives of the horses, rhinoceroses, camels, antelopes, and carnivores, and corresponds very closely to the assemblage from the Barstow formation of the Mojave Desert region. Thus the lower part of the Mint Canyon formation is Barstovian, or late Miocene, in age (fig. 2).

The younger mammalian material in the Mint Canyon formation, which occurs in an upper sequence of coarse-grained, prevailingly light-colored strata (fig. 3), may comprise two faunas of differing ages. It includes a *Hipparion* very similar to a well-known species from the Ricardo fauna of the Mojave Desert region. This is a horse with higher-crowned teeth as compared to *Merychippus* of the Barstow formation. Largely on the basis of this horse, the upper part of the Mint Canyon formation is dated by many vertebrate paleontologists as later Clarendonian (early, but not earliest Pliocene of the mammalian chronology). Other vertebrate paleontologists, in contrast, regard this occurrence as representing the first appearance of *Hipparion* in North America during Barstovian (late Miocene) time, whence the genus migrated to Europe. In Europe the genus first appears in strata of the Sarmatian stage, which is regarded by these same investigators as latest Miocene in age.

The Mint Canyon strata are overlain with distinct angular unconformity by the marine Castaic formation (Winterer and Durham, Eastern Ventura basin Map Sheet, this volume), the Modelo(?) or "Modelo" formation of earlier investigators. These marine beds contain molluscan, echinoid, and foraminiferal faunas that have been dated as of probable "Cierbo" age in part and as of "Neroly" age in the megafaunal sequence, and in part as of Mohnian age in the microfaunal sequence (Durham, 1948; White and Buffington, 1948; Wright, 1948). In both marine classifications the assigned ages are referred to the upper Miocene.

These relations point up a serious discrepancy between the invertebrate chronology and the vertebrate chronology that is favored by many paleontologists (fig. 2), a discrepancy that can be resolved only by agreement among paleontologists as to the formational and

faunal successions, which is fundamental to correlation of these chronologies with the Lyellian epochs. The problem is summarized in figure 4, in which the positions of the Mint Canyon formation and overlying marine strata are plotted, according to each of the chronologies, with respect to a horizontal line denoting the Miocene-Pliocene boundary.

Puente Formation. Somewhat similar problems of dating are posed by occurrences of fossil mammals in the marine Puente formation of the Puente Hills, in southeastern Los Angeles County (fig. 1). These scattered remains include *Hipparion,* and may occur in strata that contain a lower Mohnian microfauna. There appears to be some doubt, however, as to the true stratigraphic relationships of the only definitive vertebrate material, a horse tooth.

Maricopa Shale. A thick section of Maricopa shale, in which fossiliferous nonmarine strata are present, is well exposed in Quatal and Apache Canyons, in the upper part of the Cuyama River drainage near the northwest corner of Ventura County (fig. 1). The vertebrate assemblage includes horses, oreodonts, a camel, a mastodont, a carnivore, rodents, and birds, and in part appears to be of Barstovian age. It is distinctly younger than the fauna of the Tecuya formation, and perhaps is in part of the same age as the Barstovian fauna from the Mint Canyon formation (Gazin, 1930, p. 63). On the other hand, some of the forms appear to be of Clarendonian age, and it seems best to divide the known vertebrate assemblage into two distinct faunas (C. L. Gazin, personal communication). Further stratigraphic study of the fossil occurrences might well disclose relations similar to those of the Mint Canyon formation.

The Maricopa shale is underlain by the marine Vaqueros formation (fig. 2), and is overlain unconformably by marine "Santa Margarita" strata of late Miocene age. Marine beds within the Maricopa section permit dating of the vertebrate-bearing strata as Temblor (Gazin, 1930, p. 61) or slightly younger. Thus a Barstovian age for the vertebrate-bearing strata is reasonably compatible with the age indicated by the megafaunal invertebrate sequence, but a younger age assignment for some of the veterbrate remains once again would raise the Miocene-Pliocene boundary problem that already has been discussed.

Santa Margarita and Chanac Formations. Vertebrate fossils occur beneath the marine part of the "Santa Margarita" formation in the Comanche Point area of the Tejon Hills, south-southeast of Bakersfield (fig. 1). Four miles south-southeastward, a slightly older assemblage (the lower fauna of Tejon Hills) is present in beds that also are regarded as nonmarine parts of the "Santa Margarita" section. This older fauna has been interpreted as latest Miocene in age by some investigators (e.g., Drescher, 1941, p. 8), and as Clarendonian in age by others (e.g., Stirton, 1939a). Marine fossils from the "Santa Margarita" strata (Nomland, 1917, p. 302) indicate a Neroly age in the megafaunal sequence, and thus the relations of the vertebrate and invertebrate chronologies correspond, in general, to those in the Mint Canyon area.

The younger fauna, from strata beneath marine beds of the "Santa Margarita" formation, appears to be Clarendonian in age (Durham and Savage, 1954). A third, still younger, fauna has been obtained from the conformably overlying beds of the Chanac formation, and is of later Clarendonian age (fig. 2).

At Cammatta (Commatti) Ranch, on the Highland monocline about 20 miles southeast of Paso Robles (fig. 1), a vertebrate fauna has been obtained from what appears to be an interval just below the base of the marine Santa Margarita formation. This fauna is Clarendonian in age (Durham and Savage, 1954), whereas the age of the associated marine strata would approximately correspond to the boundary between the Mohnian and Delmontian stages of the microfaunal sequence (Kleinpell, 1938, fig. 6).

The occurrence of the fossil dog *Osteoborus* in the marine Santa Margarita formation at Crocker Springs (VanderHoof, 1931; Barbat and Weymouth, 1931), on the west side of the San Joaquin Valley (fig. 1), is thought by many vertebrate paleontologists to suggest an early Clarendonian age. These strata would be regarded as upper Miocene in terms of the invertebrate chronology.

Neroly Formation. The marine Neroly formation, on the west side of Mount Diablo in the San Francisco Bay region, yields fossil remains of the horse *Nannippus tehonensis* (Merriam). This indicates an early Clarendonian age (Stirton, 1939b, p. 350). A few miles southeast along the strike from the Neroly occurrence and about 2,000 feet higher stratigraphically, the well-preserved Black Hawk Ranch mammalian fauna (Macdonald, 1948; Richey, 1948) from the continental Green Valley formation indicates a later Clarendonian age, and may be in general correlative with the upper fauna of the Mint Canyon formation (fig. 2). It will be recalled that this upper Mint Canyon fauna is from beds that lie unconformably *beneath* the marine correlative of the Neroly and Cierbo formations. This discrepancy in marine and nonmarine correlations between central and southern California is one of the outstanding problems of current stratigraphic interpretations in the State.

Strata of the Coalinga-Kettleman Hills Area. In the North Coalinga district (fig. 1), northwest of Tulare Lake and about half-way up the west side of the San Joaquin Valley, abundant vertebrate

remains have been taken from a locality known as the *Merychippus* quarry (or *Merychippus* "zone"). The fauna contains four canine genera, one species of rodent, two species of *Merychippus* (a grazing-browsing horse), three other species of horses, a rhinoceros, a mastodont, a peccary, a cervid, and three species of camels (Merriam, 1915; Bode, 1934, 1935). The genera relative to which this assemblage could be compared directly with mammals from the Miocene series of Europe are the mastodont, *Amphicyon*, *Hemicyon* ?, and *Monosaulax* (G. E. Lewis, personal communication), but thus far the dating of this fauna has been based exclusively on the evolutionary advancement of the exclusively North American merychippine horses relative to the horses in other, more complete, North America faunas. On this basis the North Coalinga site is believed to be Barstovian (late Miocene) in age, possibly early Barstovian. The quarry is a short distance stratigraphically above the "Button Bed" of the marine Temblor formation, and thus corresponds either to the upper Relizian stage or about to the boundary between the Relizian and Luisan stages (mid-Miocene of the mircofaunal classification). It is at the top of the Temblor formation and "stage" (mid-Miocene of the megafaunal classification). Here, therefore, there is little discrepancy of dating between the terrestrial and marine classifications.

Terrestrial vertebrates are known from both marine and non-marine strata elsewhere in the North Coalinga district (fig. 2). The horse *Pliohippus coalingensis* (Merriam) was found about midway in the type section of the marine Jacalitos formation by W. P. Popenoe (unpublished data), and in the so-called "nonmarine Jacalitos" beds as well as in the overlying marine Etchegoin strata northeast of Coalinga (Nomland, 1916). The horse *Neohipparion molle* (Merriam) also was found in the "nonmarine Jacalitos." The Jacalitos formation is conventionally considered to be lower Pliocene in the marine chronology based on mollusca and echinoids, whereas the horses would indicate a later Hemphillian age (late mid-Pliocene) in the terrestrial mammalian chronology of many paleontologists.

Woodring, Stewart, and Richards (1941, p. 98) cite the occurrence of horse teeth in the *Siphonalia* and *Patinopecten* "zones" of the Etchegoin formation of the Kettleman Hills district. These teeth were identified by Stock as belonging to the genus *Pliohippus,* and were thought by him and others to indicate a Clarendonian age in terms of the mammalian chronology. It seems possible, however, that the teeth could as well represent a horse of Hemphillian age (middle Pliocene). The Etchegoin formation is considered to be middle Pliocene in the marine sequence, also (Weaver, et al., 1944).

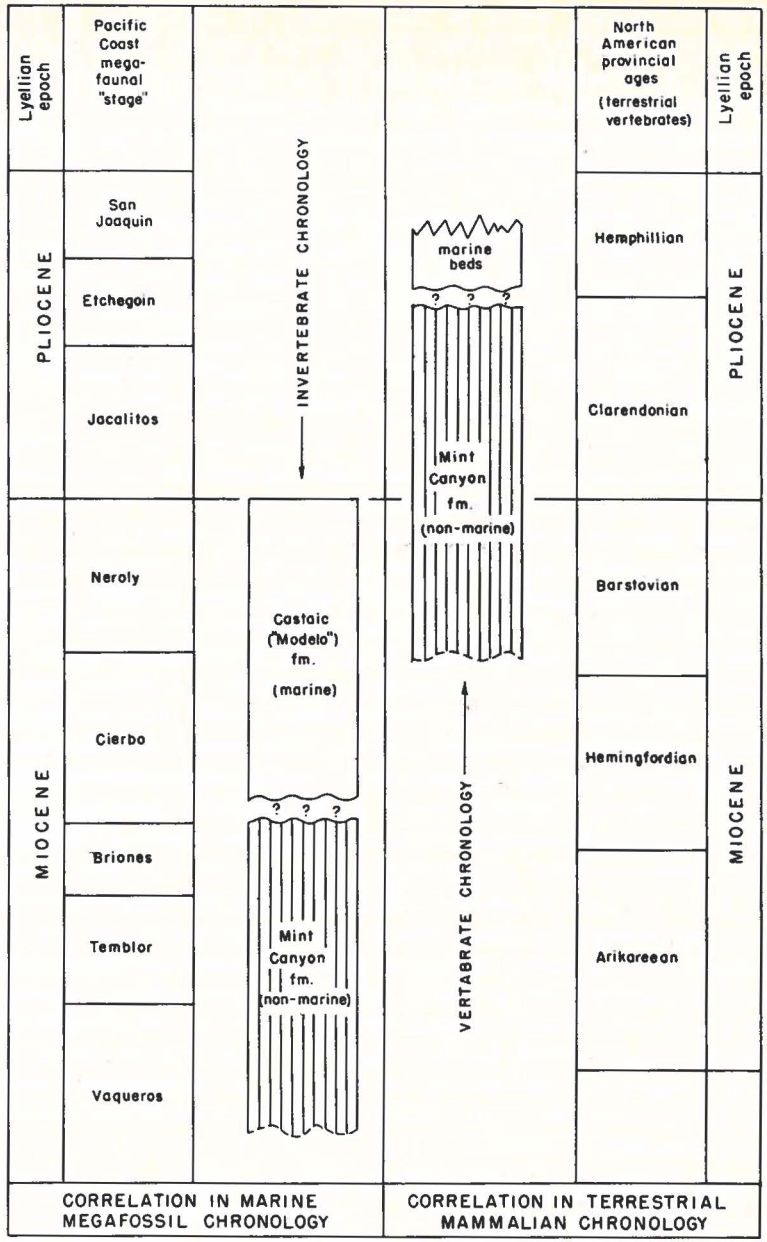


FIGURE 4. Chart showing discrepancy between vertebrate and invertebrate chronologies, as applied to the upper part of the Mint Canyon formation and to the overlying marine strata. Positions of the stratigraphic units are plotted, on the basis of the respective chronologies, with reference to a horizontal line that denotes the Miocene-Pliocene boundary.

The San Joaquin formation is the uppermost of the more purely marine units in the San Joaquin Valley. Customarily it has been referred to the upper Pliocene (Woodring, 1952) in both the marine and nonmarine chronologies of the Pacific Coast. It is to be noted, however, that if the vote of the last International Geological Congress (1948) to place the beginning of the Pleistocene epoch at the beginning of the Calabrian (marine) = Villafranchian (nonmarine) stage (Moore, 1949) is followed, the San Joaquin formation probably can be regarded as basal Pleistocene, because it can be referred to the Blancan provincial age of the North American mammalian chronology, at least part of which in turn can be correlated in a general way with the Villafranchian stage of Europe. Mammals found in the San Joaquin strata (Woodring, Stewart, and Richards, 1941, pp. 97-98) include camels, peccaries, *Equus (Plesippus)*, *Castor* (beaver), *Odocoileus* (deer), and Pliomastodon. The horse is very similar to European species from deposits termed Villafranchian or Astian by different authors. These deposits include strata in the type area of the Pliocene series.

Strata of Quaternary Age. The name "*Equus* cf. *occidentalis*" has been applied to numerous isolated bones and tooth fragments obtained from beds called San Pedro or Las Posas (Bailey, 1943; Pressler, 1929; Woodring, 1952), and this name even has been cited as characteristic for the equid material in formations of post-Pleistocene age in the succession of the Los Angeles area (Natland, 1953). The name *Equus occidentalis* has come to mean a large horse comparable to that found in the Rancho La Brea tar pits, but most of the specimens concerned could be referred to any of the larger species of *Equus*. The frequent application of this name to specimens that actually are indeterminable has given to it a halo of preciseness and chronological specificity that is wholly synthetic. As pointed out by Savage (1951), one of the two type teeth of this species was obtained from deposits of Blancan (late Pliocene) age in Kern County, and the other was obtained from gravels in the Sierra Nevada at an unspecified locality in Tuolumne County. Topotype material from the Kern County locality indicates a Blancan age. According to Woodring (1952), the Santa Barbara formation, the San Pedro formation of Bailey, the Las Posas formation, and the type San Pedro formation are all of a Pleistocene age younger than the San Joaquin formation.

Insofar as known mammalian remains are concerned, the complex of intergrading formations that have been termed Saugus, Santa Barbara, San Pedro, and Las Posas in the Ventura basin, the Los Angeles basin, and in border areas probably range in age from Blancan (late Pliocene) through Irvingtonian (earlier Pleistocene), and perhaps through Rancholabrean (later Pleistocene). The evidence thus far marshalled, however, is purely suggestive.

One of the youngest marine-nonmarine "tie-ins" in southern California occurs in the Palos Verdes sand in San Pedro, at the Lumber Yard locality of various writers (Woodring, Bramlette, and Kew, 1946, p. 86). Here a Rancholabrean (later Pleistocene) age is indicated by the presence of *Bison* and species of smaller mammals that still survive in the area. The Palos Verdes sand is considered to be no older than late Pleistocene by practically all paleontologists (Woodring, 1952, pp. 405-406, fig. 1), no matter what criteria are used. The terrace on which this deposit occurs is the lowest of 13 upper Pleistocene marine terraces that are present in the Palos Verdes Hills.

Summary. As indicated in figure 2 and in the foregoing paragraphs, discrepancies between invertebrate and some vertebrate correlations are present at many localities in California where both marine and nonmarine strata are juxtaposed or show interfingering relations. This is scarcely surprising when it is recalled that the terrestrial vertebrate chronology and the marine megafaunal and microfaunal chronologies have been established more or less independently on the basis of relations in widely scattered areas, very few of which include localities discussed in this paper. The most serious of the discrepancies involves the interval upper Miocene—lower Pliocene, and involves problems of faunal and stratigraphic correlation, as well as some purely terminologic difficulties.

At the present time, the available evidence is not adequate to resolve many of the difficulties in correlation and dating, but the following possibilities should be considered:

1. The indicated correlations of any or all of the three chronologies with the European reference section may be incorrect.
2. The time spans of some units in any of the chronologies may be greater than is ordinarily estimated.
3. Many fossils now considered to be time-stratigraphic indices are not such, but instead are only facies indicators.
4. The time span involved in dispersal of faunas, or certain critical members of faunas, may be greater than is currently recognized.
5. Some of the European reference stages may be facies of other stages rather than sequential to them (cf. Gignoux, 1943, and Movius, 1949).
6. The stratigraphic relations between terrestrial vertebrate-bearing strata and marine invertebrate-bearing strata may be incorrectly reported or imperfectly understood in some areas.

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